Specifications for Small Earth-fill Dams on Foundation of Fine Grained Soils

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Ministry of Natural Resources
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TABLE OF CONTENTS

INDEX

	PAGE NO.
INTRODUCTION	1
COMMON PROBLEMS ASSOCIATED WITH SMALL DAMS	1
SPECIFICATIONS FOR SMALL EARTH-FILLED DAMS	3
A. PRELIMINARY PHASE	4
1. General Site Selection For Dam and Reservoir	4
2. Surveys and Investigations	4
B. DESIGN PHASE	
1. Purpose of Design	7
2. Design and Specifications of Earth-Filled Dam Embankment	10
3. Design of Cut-Off Trench	11
4. Freeboard Requirements	12
5. Stability Requirements	12
6. The Drop-Inlet Spillway	13
7. Water Supply - Drain Pipe	16
8. The Emergency Spillway	16
9. Environment Protection	17
C. CONSTRUCTION PHASE	17
POST CONSTRUCTION CONSIDERATIONS	18
SUMMARY	18
TABLE I - Unified Soil Classification System - Suitability for Construction	
TABLE II - Laboratory Criteria	
TABLE III - Typical Optimum Moisture Content Values	

INTRODUCTION

Under the Lakes and River Improvement Act, dams constructed on Lakes and Rivers must be approved by The Ministry of Natural Resources. The approval of small earth-fill dams is conditional upon compliance with these specifications.

The specifications in this booklet apply only to small earth-fill dams. Large dams, as defined below, must be designed and stamped by a Registered Professional Engineer before they can be approved:

1. Dams with a height of 3 m (10 feet) or more above the original streambed.

2. Dams with a height of 2 m (6 feet) or more above the original streambed and a reservoir surface area, at normal water level, of 2 hectares (5 acres) or more.

3. Dams with a watershed area of 5 square kilometers (2 square miles) or more.

4. Dams, the failure of which could cause loss of life or property damage in excess of $50,000.

5. Dams, the failure of which could release a pollutant likely to impair the quality of the stream.

Any dam, which may be classified as a small dam, but is not an earth-filled dam, must also be designed and stamped by a Registered Professional Engineer.

COMMON PROBLEMS EXPERIENCED WITH SMALL DAMS

1. Dams built on very soft soils can have serious shear and bearing problems/failures.

COMMON PROBLEMS EXPERIENCED WITH SMALL DAMS (continued)

2. Erosion of the downstream slope due to seepage.

3. Excessive seepage under the dam from pervious upstream material in the reservoir.

4. Overtopping of the dam, when spillway capacities are inadequate.

5. Piping or progressive erosion of concentrated leaks due to poor construction practice, i.e. poor compaction.

6. Sloughing or ravelling of the downstream slope. Starts when small amounts of materials at the toe erode and cause a miniature slide.

7. Differential settlement cracks caused when the embankment is subjected to differential settlement.

8. Reservoir wave action during bad storms, when upstream slope is not protected properly or not enough freeboard is provided.

9. Damage due to burrowing animals.

10. Damage due to surface drying caused by some combination of the following three factors:

    i) hot, dry climate during which the reservoir remains empty for long periods of time.

COMMON PROBLEMS EXPERIENCED WITH SMALL DAMS (continued)

ii) embankment construction material are highly plastic or consist of extremely fine silty soil.

iii) embankments have not been compacted to a high density.

A Registered Professional Engineer or an experienced contractor should be contacted for assistance in applying these specifications in most cases. Although engineering drawings are not essential, they are useful for determining cut and fill requirements and ensuring that the design standards are met. Standard drawings available from The Ministry of Agriculture and Food and the Ministry of Natural Resources, are valuable aids to design.

SPECIFICATIONS FOR SMALL EARTH-FILLED DAMS

The specifications for small earth-filled dams are divided into 3 major categories; namely:

1. Preliminary Phase - In this phase all exploratory surveys and investigations are carried out to select the most suitable dam site location; to locate the suitable borrow material and provide information for the design stage.

2. Design Phase - Based on the findings of the preliminary phase, designs are prepared for the dam and associated structures as well as specifications for a contractor to construct the designed structure.

3. Construction Phase - In this phase the structure is constructed according to the specifications prepared in the design stage.

SPECIFICATIONS FOR SMALL EARTH-FILLED DAMS (continued)

3. Construction Phase (continued)

Construction control and verification must also be provided to ensure that the structure is built according to the specifications.

A. PRELIMINARY PHASE

1. General Site Selection For Dam and Reservoir

A small dam may only be constructed where site and soil conditions are suitable. The site should be located in a narrow section of the stream channel and where both abutments have sufficient height for the need. The foundation, including abutments should be of sufficiently strong material to support the structure. Impervious soil must be at or near the ground surface, so that seepage is prevented. Pervious soils, such as sands and gravels, are not suitable for construction and if they are encountered, an engineer must be consulted before construction is undertaken.

In order to obtain an economical storage capacity, the reservoir site should be wide in comparison to the dam site and should be on a stream having a low or gentle gradient to obtain a long reservoir in comparison to the height of the dam. It should not be on formations that leak excessively, i.e. the soil at the base of the reservoir should contain a layer of material that is impervious and thick enough to prevent excessive seepage.

2. Surveys and Investigations

a) Dam Site

The minimum survey for this should include a profile of

A. PRELIMINARY PHASE (continued)

2. Surveys and Investigations (continued)

a) Dam Site (continued)

elevations on the axis of the proposed dam. This will be useful for fill requirements and estimating construction costs.

The investigation for the dam should include a number of test pits or borings along the line of the proposed dam and if possible, at the abutment locations. The test pits or borings along the foundation of the dam should be spaced between 15 m and 25 m and extend to a depth below ground surface equal to 1.5 times the height of the dam. If poor soils are encountered, the depth of the test pits or borings may have to be increased. In this case, an engineer's decision will be required.

For the reservoir area test pits or borings should be put down at intervals over the area to be covered with water. Generally two test pits or borings per acre may be sufficient if the subsoil conditions are uniform. The number of test pits or borings should be increased if there are significant changes in the soil types.

A number of test pits or borings should also be put down in the area which will be used as a source of borrow material. The test pits should be spaced to provide a good coverage of the borrow area. The depth of the test pits or borings should reflect the amount of borrow material required.

Bulk or disturbed samples should be retrieved from each of the test pits or borings from all three areas; i.e. from the proposed dam location, the reservoir and the borrow area. The samples should be placed in plastic sample bags and sealed so that the natural moisture content is maintained.

A. PRELIMINARY PHASE (continued)

2. Surveys and Investigations (continued)

a) Dam Site (continued)

The samples should be preserved for later laboratory analyses and testing. All soils should be classified in accordance with the Unified Classification System (See Table II).

On selected samples, laboratory testing should be carried out. The amount of laboratory testing will depend on the size of the project and the soil types encountered. In general, the testing should include, but not necessarily limited to, the following tests:

AREA	LABORATORY TESTS
Dam Site	- natural moisture contents - permeability tests (if required) - grain-size distribution tests - strength assessment*
Reservoir Site	- grain-size distribution tests - permeability tests (if required)
Borrow Area	- natural moisture content - standard Proctor density test - grain-size distribution tests
* The strength assessment could also be made during the field Investigation.	

It is strongly recommended that a qualified Registered Professional Engineer be involved in the investigation of the proposed dam project. The laboratory testing should be carried out by a qualified

A. PRELIMINARY PHASE (continued)

2. Surveys and Investigations (continued)

a) Dam Site (continued)

testing company. An understanding of the results of the investigation and the resulting design of the most economical and safe dam can best be worked out in conjunction with a Registered Professional Engineer.

B. DESIGN PHASE

1. The Purpose of Design

The small earth-filled dam consists of three major components:

a) The embankment,
b) the drop-inlet spillway; and
c) the emergency spillway.

These components are illustrated in Figures 1 and 2. The purpose of design can be summarized as follows:

i) The embankment must be safe against overtopping during occurrence of the design flood by provision of sufficient spillway and outlet works capacity. The emergency spillway passes water around the dam when flows exceed the capacity of the drop-inlet spillway and must be designed to accommodate the 25 year* flood, or greater.

ii) The slopes of the embankment must be stable during construction and under all conditions of reservoir operations.

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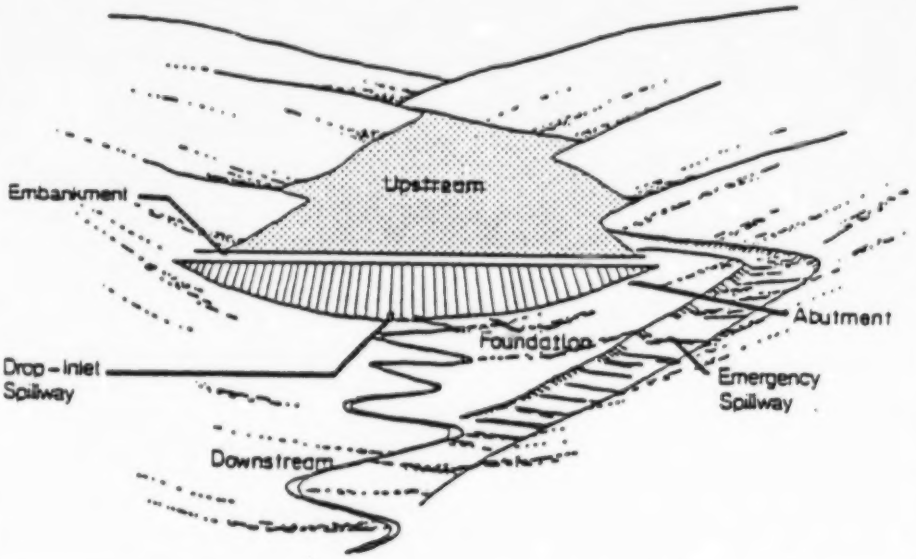
*A 25 year flood is the flood which is likely to be equalled or exceeded once in 25 years.

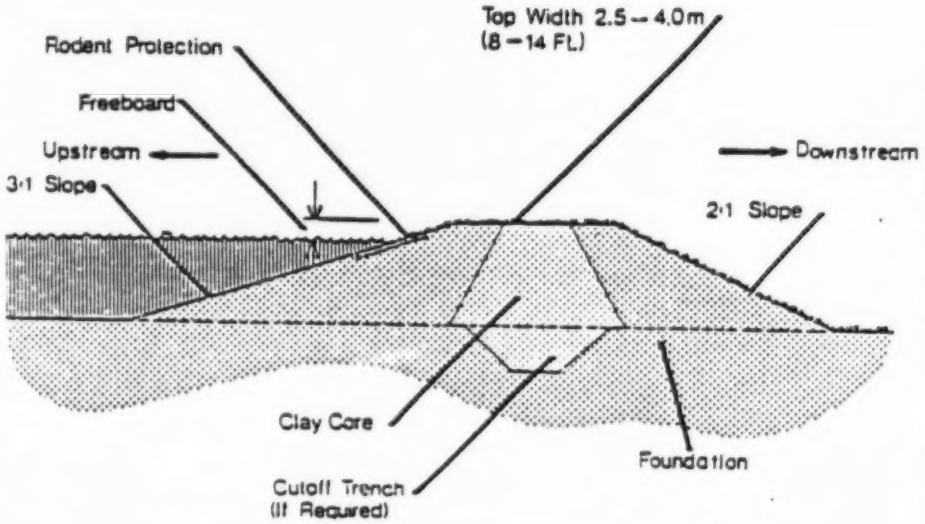
Typical Small Earth Dam

Fig. 1



Cross-Section

Fig. 2



B. DESIGN PHASE (continued)

1. The Purpose of Design (continued)

iii) The embankment must be designed so as not to impose excessive stresses upon the foundation.

iv) Seepage flow through the embankment, foundation and abutment must be controlled.

v) The embankment must be safe against overtopping by wave action.

vi) The upstream slope must be protected against erosion by wave action and the downstream must be protected against erosion due to rain and wind.

vii) The drop-inlet spillway must be designed to drain excess water from the reservoir under normal conditions. It must, therefore, be large enough to accommodate normal discharge from the Stream (see also Section B6).

The term "foundation" refers to both the valley floor and the abutments. The essential purpose of a foundation for an earth-filled dam is to provide stable support for the embankment under all conditions of loading and saturation and to provide sufficient resistance to passage of water.

Foundations are grouped into three main classes:

a) Foundations of bedrock.
b) Foundations of coarse-grained soils (sand and gravel).
c) Foundations of fine-grained soils (silts and clays).

The specifications in this booklet are only applicable for the third case. They are not applicable for the first and second cases.

B. DESIGN PHASE (continued)

1. The Purpose of Design (continued)

The only exception is when, in the second case, the depth of the coarse-grained material is less than one-third the height of the dam and the upper coarse-grained material is followed by a thick impervious stratum.

2. Design and Specifications of Earth-Filled Dam Embankment

One of two methods can be used for construction:

a) If an adequate supply of suitable impervious soil is available, the entire dam is constructed of this material. This type of dam is referred to a "homogeneous type" dam.

b) Where suitable impervious soil is in short supply, the available impervious soil is used to construct a "clay core" on top of the clay cut-off trench (see Figure 2) to seal the dam against seepage. Other more pervious soil is then used on the upstream and downstream sides of the dam. The top width of the clay core must be a minimum of 1.5 m (5 feet) and the sides must not exceed 1:2; i.e. 1 horizontal to 2 vertical. This type of a dam is referred to as a "Diaphragm Type" Dam.

The embankment regardless of whether it is homogeneous or zoned, should be compacted in thin layers of 15 cm (6 inches) to 20 cm (8 inches) to 100 per cent of the material's maximum dry standard Proctor density. The fill material used for constructing the dam embankment must be free of stones over 15 cm (6 inches) in size, vegetation, stumps, frozen soil and other foreign materials. The degree of compaction is related to the moisture content of the material as well as to the compactive effort provided. The choice of the size and type of the compaction equipment should be such that a layer of a certain thickness can be compacted through its entire depth. Table I suggests different types of compaction equipment for various types of materials. An approximation of the optimum moisture contents for different soil types is given in Table III.

B. DESIGN PHASE (continued)

2. Design and Specifications of Earth-Filled Dam Embankment (cont'd)

In the case of a "diaphragm type" dam, the clay core should consist of a fine-grained material having a coefficient of permeability in compacted state of less than 10^{-6} cm/sec. The material should be placed and compacted as described above to 100 percent of the material's maximum dry standard Proctor density. In order to accomplish this degree of compaction, the natural moisture content must be strictly controlled and be within ±1.5 per cent of the optimum moisture content. A suitable size roller (preferably a sheepsfoot) should be used. In-place field density tests must be performed by a qualified testing agency in each layer, to verify that required degree of compaction has been achieved. Only once the required compaction has been achieved should the next layer be placed and compacted.

3. Design of Cut-Off Trench

If impervious soil lies below the surface layer of pervious soil (sand and gravel) and if the thickness of the pervious layer is less than one-third the height of the dam, a "cut-off trench" must be dug down into the impervious soil. This trench should be backfilled with clayey material (coefficient of permeability of less than 10^{-6} cm/sec.) in shallow lifts and compacted as described before. The purpose of this "cut-off trench" is to prevent water from seeping under the dam. The bottom of the trench should be roughened to provide a better bond with the native impervious soil and the clayey soil.

The trench must be dug a minimum of 30 cm (12 inches) into the impervious soil, and must be a minimum of 1 m (3 feet) wide at the bottom, with side slopes no steeper than 1:1 (see Figure 3).

B. DESIGN PHASE (continued)

4. Freeboard Requirements

The fill should be placed and compacted in lifts as specified until the desired height is reached. To protect the dam against overtopping by waves and flooding, adequate freeboard must be provided (the height of the dam above the proposed water level). Minimum requirements are listed below.

POND SIZE	FREEBOARD
Pond less than 200 m (660 feet)	30 cm (1 foot)
Pond between 200 and 400 m (660 to 1320 feet) long	45 cm (1.5 feet)
Pond up to 800 m (0.5 miles) long	60 cm (2 feet)
Pond over 800 m long	Consult an engineer

5. Stability Requirements

To ensure stability, the upstream slope of the dam should be graded to a 3:1 slope, while a 2:1 slope will be adequate for the downstream side. In some cases, flatter slopes may be required if the soil used as fill is unstable or if the founding subsoil is very weak.

B. DESIGN PHASE (continued)

5. Stability Requirements (continued)

The finished top width of the dam must be at least 2.5 m (8 feet) unless it is used as a roadway, in which case it must be 4 m (14 feet) wide. Unstable soil may necessitate a wider dam.

The dam should be stabilized by planting and maintaining a dense cover of grass. Protection from burrowing animals that may damage the dam is recommended. Galvanized wire mesh with openings of 60 mm (2½ inches) or less can be burried 30 cm (1 foot) below the surface of the slope. It should extend 120 cm (4 feet) above and below the normal water level.

Below the outlet of the drop-inlet spillway, adequate erosion protection is required. Suitable rip-rap or gabion baskets are generally used. Rip-Rap consists in most cases, of stones 30 cm (1 foot) in diameter layed on a filter of finer granular materials, such as gravel-sand mixture, which prevents the soils beneath the rip-rap from being washed out.

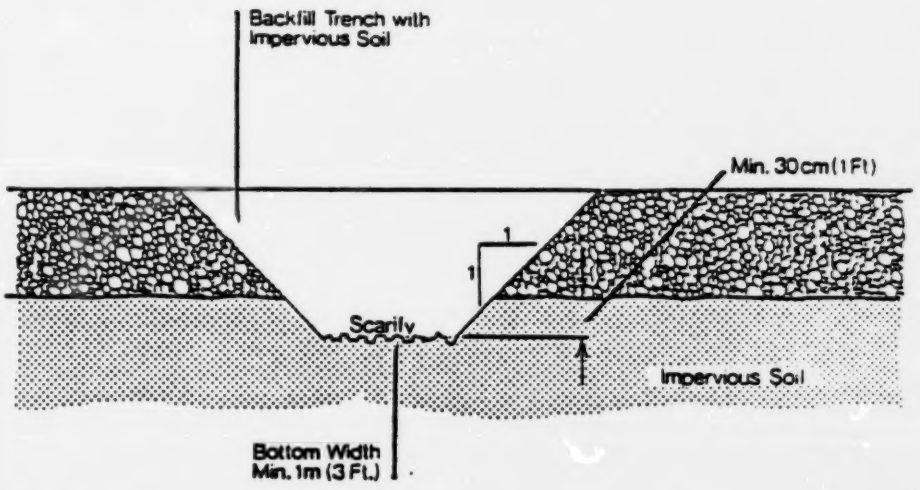
6. The Drop-Inlet Spillway

The drop-inlet spillway consists of two major parts: the riser and the outlet pipe (Figure 4). In some cases, where downstream water temperatures or pond water levels must be controlled, the Ministry of Natural Resources may require the installation of a bottom-draw off (Figure 5). It draws cooler water from the bottom of the pond, and stop-logs, installed in the riser, regulate water levels.

The riser and outlet must be designed to accommodate 20 percent of the flow resulting from the 25 year flood. If stop-logs are installed, a larger riser is required. A bottom draw-off pipe must accommodate the average Summer flow of the Stream.

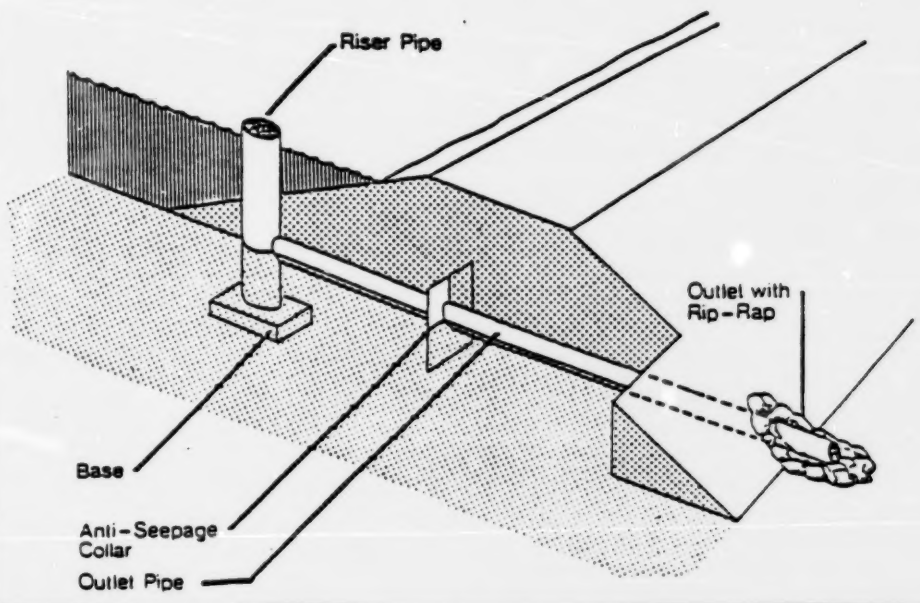
Typical Cutoff Trench

Fig. 3



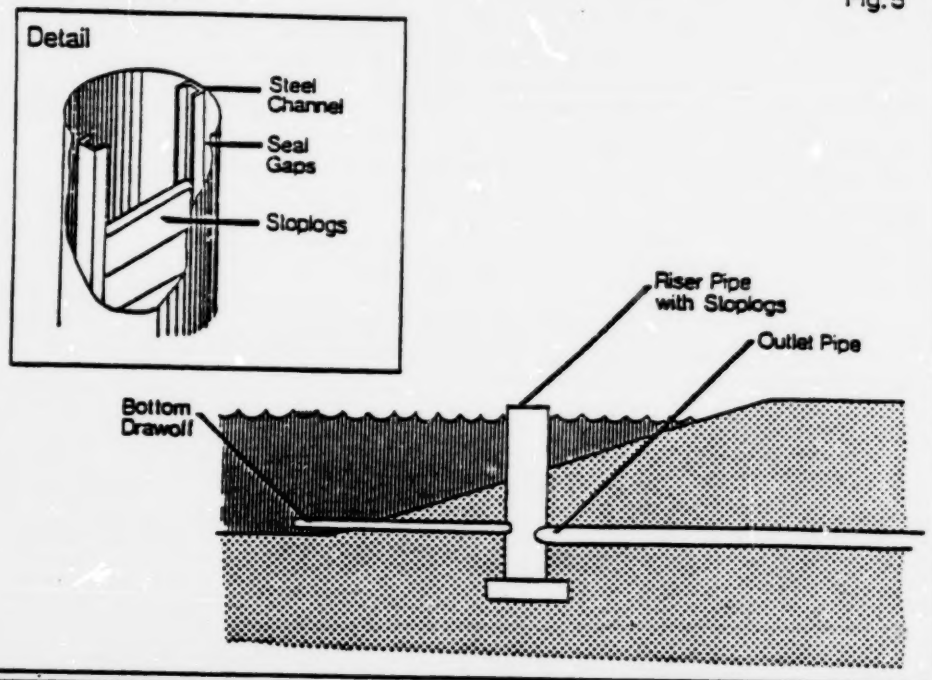
Cutaway View of
Drop-inlet Spillway

Fig. 4



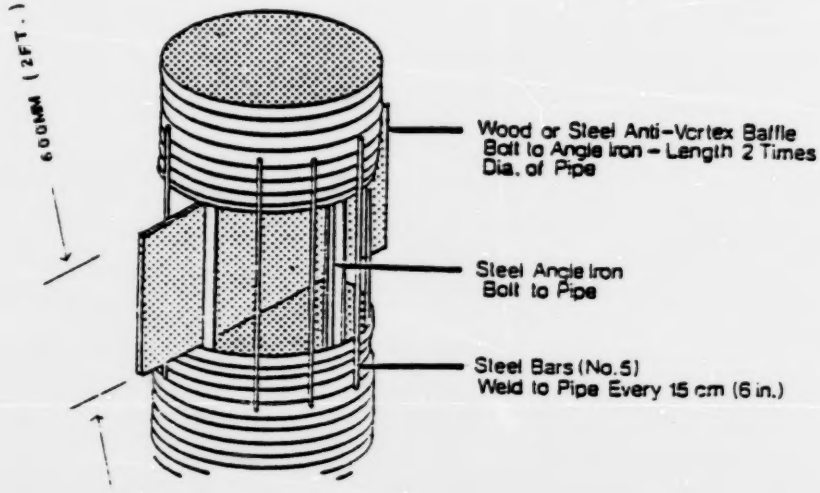
Bottom Drawoff

Fig. 5



Trash Rack/Anti-Vortex Baffle

Fig. 6


600MM (2FT.)
Wood or Steel Anti-Vortex Baffle Bolt to Angle Iron – Length 2 Times Dia. of Pipe
Steel Angle Iron Bolt to Pipe
Steel Bars (No. 5) Weld to Pipe Every 15 cm (6 in.)

B. DESIGN PHASE (continued)

6. The Drop-Inlet Spillway (continued)

Corrugated metal pipe is suitable for the construction of the drop-inlet spillway but other materials, including concrete pipe and poured-in-place concrete, may also be used. In all cases, manufacturers' specifications must be observed. The following specifications relate to the installation of the drop-inlet spillway.

a) Pipe sizes must be specified by a Registered Professional Engineer.
b) The riser must be secured to a concrete slab 50 cm (20 inches) thick and twice the diameter of the riser in width layed on a properly compacted base. Alternatively, a rock-filled base may be used.
c) Lay the outlet pipe on a well compacted base; insure that fill placed around and over the pipe is well compacted, so that seepage is prevented. One or more anti-seepage collars must be installed in the impervious section of the dam. Space the collars 3 m (10 feet) to 7 m (21 feet) apart.
d) All connections must be waterproof. If metal pipe is used, weld the riser to the outlet and cover with sealant; use collars to join sections of pipe and waterproof the joints with sealant or by using neoprene seals.
e) The drop-inlet must be provided with an anti-vortex baffle and a trash rack (See Figure 6).
f) The outlet must be extended beyond the toe of the dam's downstream slope to protect against erosion; rip-rap or gabion baskets may be required for additional erosion protection.

B. DESIGN PHASE (continued)

6. The Drop-Inlet Spillway (continued)

g) All poured-in-place concrete must be designed to withstand stresses imposed in accordance with sound engineering principles and reinforced with steel bars as required. Concrete must be of high quality and have a minimum strength of 25 MPa (3600 psi).

7. Water Supply - Drain Pipe

A separate pipe may be installed to provide water for livestock and irrigation, and/or to drain the pond. Often a 37 mm (1½ inch) diameter pipe is used for stock watering, but a larger pipe may be required for irrigation. Plastic, concrete or metal pipe may be used, provided that manufacturers specifications are followed.

Install a gate valve so that water supply can be controlled and equip the inlet with a filter. Specifications relating to the installation of the bottom draw-off also apply to the water supply-drain pipe.

8. The Emergency Spillway

Emergency spillway dimensions and slope must be specified by a Registered Professional Engineer. The spillway must be provided with a control section, a level section at least 6 m (20 feet) long, which controls the flow of water through the spillway. The relative elevations of the top of the dam, the drop-inlet and the emergency spillway's control section are critical to the proper operation of the dam and must be specified by a Registered Professional Engineer.

The design must ensure that water discharges from the emergency spillway downstream of the dam, so that the embankment is not undermined.

B. DESIGN PHASE (continued)

8. The Emergency Spillway (continued)

Erosion protection is critical; stabilize the spillway by planting and maintaining a dense cover of grass. The inlet and outlet must be flared to permit water to flow smoothly.

9. Environment Protection

The landowner must minimize the adverse environmental impacts of construction.

The disturbed area should be minimized so that excessive amounts of soil are not washed into the stream. As soon as construction is completed, bare soil must be revegetated at both the dam site and the borrow pit. Where applicable, the dam construction should not be undertaken when valuable fish species may be spawning downstream; increased sediment in the stream may prevent spawning. A sediment trap may be used during construction.

C. CONSTRUCTION PHASE

Small dams must be constructed according to sound engineering principles and show a high standard of workmanship. Where applicable, the Ontario Building Code and the Ministry of Transportation and Communications specifications must be adhered to.

Inspection during the construction phase, by a Registered Professional Engineer may be required where sites are not straightforward. In-place field density tests must be performed by a qualified testing firm within each layer, which is not to exceed 20 cm (8 inches). As a minimum, one compaction test must be obtained for every 150 sq. m. For acceptability, at least 90 per cent of the tests must indicate degree of compaction in

C. CONSTRUCTION PHASE (continued)

excess of 100 per cent maximum dry standard Proctor density. However, 100 per cent of the tests must be better than 95 per cent standard Proctor density.

POST CONSTRUCTION CONSIDERATIONS

The dam should be inspected periodically for damage. Eroded areas should be repaired and replanted with grass as a preventative measure. It may be necessary to mow the emergency spillway periodically so that optimum flows will be maintained during floods.

During the Winter, the pond should be drawn down so that the danger of damage to the drop-inlet by ice is minimized and so that the storage capacity is available during Spring runoff.

SUMMARY

The following information must be provided by a Registered Professional Engineer:

1. An assessment of the site.
2. Investigation for the dam, reservoir and borrow areas, including the necessary laboratory testing.
3. Drop-inlet riser and outlet sizes.
4. Emergency spillway dimensions and slope.
5. Elevations of dam, drop-inlet and emergency spillway control section.
6. Soil compaction specification.
7. Verification of compaction quality.

Under special circumstances, where unusual site conditions are

SUMMARY (continued)

encountered or there are particular concerns regarding the effect of the dam, additional information may be required.

By using information provided by a Registered Professional Engineer and specifications, a safe, effective small earth-filled dam may be constructed and approval will be extended by the Ministry of Natural Resources.

TABLE I

Unified Soil Classification System — Suitability for Construction

Soil Class	Description	Workability for Construction	Relative Permeability	Permeability cm per sec.	Resistance to Piping	Compactability	Standard Proctor Density	Recommended Compaction Equipment	General Use for Earth Dams
GW	Well-graded gravels, gravel sand-mixture, little or no fines	Excellent	High	10^{-2}	Good	Good	2000-2160 kg/m^3	Crawler tractor or vibratory steel wheeled	Very stable, pervious shells
GP	Poorly graded gravels, gravel-sand mixture, little or no fines	Good	High	10^{-2}	Good	Good	1840-2000	" "	Reasonably stable; pervious shells
GM	Silty gravels, gravel-sand-silt mixtures	Good	Medium	10^{-3}-10^{-6}	Poor	Good with close control	1920-2160	Rubber-tired or sheepsfoot	Reasonably stable but not suitable for shells; may be used for impervious core
GC	Clayey gravels, gravel-sand clay mixtures	Good	Low	10^{-6}-10^{-8}	Good	Good	1840-2080	Sheepsfoot or rubber-tired	Fairly stable; may be used for impervious core
SW	Well-graded sands, gravelly sands, little or no fines	Excellent	High	10^{-3}	Fair	Good	1760-2080	Crawler tractor and vibratory or steel wheeled	Very stable; previous shells; erosion protection required
SP	Poorly-graded sands, gravelly sands, littloe or no fines	Fair	High	10^{-3}	Fair to Poor	Good	1600-1920	" " "	Reasonably stable; pervious shells with flat slopes and erosion protection req'd
SM	Silty-sand, sand-silt mixtures	Fair	Medium	10^{-3}-10^{-6}	Poor to Very Poor	Good	1680-2000	Rubber-tired or sheepsfoot	Fairly stable, not suited for shells but may be used for impervious cores
SC	Clayey sands, sand-clay mixtures	Good	Low	10^{-6}-10^{-8}	Good	Good	1680-2000	" "	Fairly stable; use for impervious core
ML	Inorganic silts and very fine sands; silty or clayey fine sands; silty clays	Fair	Medium	10^{-3}-10^{-6}	Poor to Very Poor	Good to Poor Close Control Essential	1540-1920	Sheepsfoot	Poor stability; may be used for embankments with close control of construction
CL	Inorganic clays of low to medium plasticity; gravelly sand, silty clays	Good to Fair	Low	10^{-6}-10^{-8}	Good to Fair	Fair to Good	1540-1920	"	Stable; impervious core
OL	Organic silts and silty-clays of low plasticity	Fair	Medium to Low	10^{-4}-10^{-6}	Good to Poor	Fair to Poor	1280-1600	"	Not Suitable
MH	Inorganic silts, elastic silts	Poor	Medium to Low	10^{-4}-10^{-6}	Good to Poor	Poor to Very Poor	1120-1540	"	Not Suitable
CH	Inorganic clays of high plasticity	Poor	Low	10^{-6}-10^{-8}	Excellent	Fair to Poor	1200-1680	"	Fair stability with flat slopes; impervious cores
OH	Organic clays and silts with medium to high plasticity	Poor	Low	10^{-6}-10^{-8}	Good to Poor	Poor to Very Poor	1040-1600	"	Not Suitable
Pt	Peat and other highly organic soils								Not suitable for construction

These charts are intended for the use of a Professional Engineer in classifying soil as to suitability for dam construction.

TABLE II

LABORATORY CRITERIA					Unified Soil Classes
COARSE-GRAINED SOILS Less than half of material passes the No. 200 sieve size.	GRAVELS Less than half of the coarse fraction passes the No. 4 sieve size.	CLEAN GRAVELS Less than 5% passing the No. 200 sieve size.	WELL GRADED Meets gradation requirements	GRADATION REQUIREMENTS ARE: $C_u = \frac{D_{60}}{D_{10}} > 4$ and, $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 & 3	GW
			POORLY GRADED Does not meet gradation requirements		GP
		GRAVELS WITH FINES More than 12% passing the No. 200 sieve size	Plasticity limits of material passing No. 40 sieve size plots below "A" line or P.I. less than 4.	Plasticity limits above "A" line with P.I. between 4 and 7 are border-line cases and require use of dual symbols	GM
		Border-line cases require the use of dual symbols.	Plasticity limits of material passing No. 40 sieve size plots above "A" line with P.I. more than 7.		GC
	SANDS More than half of the coarse fraction passes the No. 4 sieve size.	CLEAN SANDS Less than 5% passing the No. 200 sieve size.	WELL GRADED Meets gradation requirements	GRADATION REQUIREMENTS ARE: $C_u = \frac{D_{60}}{D_{10}} > 6$ and, $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 & 3	SW
			POORLY GRADED Does not meet gradation requirements		SP
		SANDS WITH FINES More than 12% passing the No. 40 sieve size	Plasticity limits of material passing No. 40 sieve size plots below "A" line or P.I. less than 4.	Plasticity limits above "A" line with P.I. between 4 and 7 are border-line cases and require use of dual symbols	SM
		Border-line cases require the use of dual symbols.	Plasticity limits of material passing No. 40 sieve size plots above "A" line with P.I. more than 7.		SC
FINE-GRAINED SOILS More than half of material passes the No. 200 sieve size.	SILTS AND CLAYS Liquid limit less than 50	Below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 and border-line cases requiring use of dual symbols		ML
		Above "A" line with P.I. more than 7			CL
		Below "A" line or P.I. less than 4 & $\frac{\text{L.L. (oven dry soil)}}{\text{L.L. (air dry soil)}} < 0.7$	Plasticity Chart: (P.I.) Plasticity Index; Liquid Limit (L.L.); CH, CL, ML or OL, MH or OH		OL
	SILTS AND CLAYS Liquid limit greater than 50	Below "A" line			MH
		Above "A" line			CH
		Below "A" line and $\frac{\text{L.L. (oven dry soil)}}{\text{L.L. (air dry soil)}} < 0.7$			OH
Highly Organic Soil			$\frac{\text{L.L. (oven dry soil)}}{\text{L.L. (air dry soil)}} < 0.7$		Pt

TABLE III

APPROXIMATE RANGE OF OPTIMUM MOISTURE CONTENT VERSUS SOIL TYPE

Soil Type	Probable Value of Optimum Moisture (%) Standard Proctor Test
Sand	6 - 10
Sand - Silt Mixture	8 - 12
Silt	12 - 16
Clay	15 - 22

Consideration of reduced soils investigation for very low dams (1.5m or less)

The investigation for the dam should include a number of test holes along the line of the proposed dam. The use of a backhoe should be discouraged since it would create a fairly large excavation. Since the depth of test holes will be limited, normal mechanical or motorized post-hole diggers can be used. The test holes along the foundation should be spaced between 30 m and 45 m and should extend to a depth of 1.5 times the height of the dam. If poor soil conditions are encountered, the depth and spacing of the test holes may have to be increased. In this case, an engineer's decision will be required.

The amount of laboratory tests performed can be reduced as the height of the dam structure is reduced and also if the soil conditions are suited for dam construction.

A dam, regardless of its height, is an engineering structure and hence must be designed and constructed as one.